The Future of the Open Trace Format (OTF)
and Open Event Trace Recording

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Agenda

• Introduction
• The OTF2 event trace data format
• The Score-P measurement system for parallel performance analysis
• The Score-P Online Analysis Interface
• Connecting the TAU Performance Tools
• Conclusions and Discussion
Introduction

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What is OTF?

• Open Trace Format
• Event Tracing Data Format
• Parallel Performance Analysis

• Open Source Trace Format Library and Support Tools
• under BSD Open Source License
• originally developed by ZIH/TU Dresden (Vampir tool group) together with University of Oregon (TAU tool group) with funding by LLNL
• announced at SC'2006 BOF
OTF Features

- store events of interest with specific properties
- Typical events: enter/leave, send/receive, collective communication, hardware performance counters, and more
- Fast and platform independent,
- efficient ASCII encoding, Zlib compression
- fast selective access (for processes and time intervals)
- flexible container for n process using m streams (files)
- read/write APIs for C/C++/Python, support tools
- forward and backward compatible
OTF Adoption

Well received in HPC tools community, e.g. part of:

- VampirTrace, also integrated in Open MPI
- TAU performance tools
- OpenSpeedshop
- Sun Performance Analyzer
- Microsoft HPC Pack 2008 SDK

- many more internal/experimental tools/workflows
- from academia and industry
The Open Trace Format Version 2 (OTF2)

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Why a new format?

• OTF2 is successor format to OTF and Epilog
• Major re-design and new implementation

• Scalability limits
• Interoperability limits
Scalability Limits

• recording and interactive visualization
  – 10 000 processes/threads and
  – 100 GB to 1 TB of event trace data

• one file per process/thread created during data collection
• reduce (merge) afterwards
• over-stresses all parallel file systems

• exploding representational of process groups (MPI comm.)

• unification of identifiers/definitions requires complete copy
Interoperability Limits

Other event trace data formats very similar

- Epilog (Kojak/Scalasca)
- Paje format (Paje)
- STF (Intel Trace Analyzer)
- Tau trace format (Tau)
- Slog2 (Jumpshot)
- Paraver format (Paraver)

- Inconvenient when using multiple performance tools
- convert formats or re-run measurements
OTF2 Design Goals

• Same basic structure as OTF/Epilog/other formats
• Good read/write performance
• High scalability
• Low overhead (storage space and processing time)
• Integrate OTF2 memory buffer as data recording buffer
• Reduce number of files during initial writing via SION Library [1] http://www.fz-juelich.de/jsc/sionlib/
• Compatibility reader for OTF and Epilog formats

OTF vs. OTF2 File Layout

post-mortem merging

round-robin blocking
Integration in Measurement System

- OTF2 buffer directly integrated as measurement buffer
- Eventually store to file
- Or re-use as read buffer, avoid I/O altogether
Unification without Copying

- Unification of local IDs and timestamps
- Local-to-global mapping tables, no file copies

- Read library applies mappings on-the-fly
- Read local IDs, translate, deliver global IDs

local event recording

write buffer

mapping table

local event reading

read buffer

unified call-backs

mapping table
OTF2 Development

• OTF2 developed as part of the SILC project
• Funded by BMBF/Germany and DOE/USA

• collaboration between:
  – ZIH/TU Dresden (Vampir tool group),
  – JSC/Forschungszentrum Jülich and German Research School for Simulation Sciences (Scalasca tool group)
  – University of Oregon (Tau tool group)
• Open for other tools/groups

• maintainers: Dominic Eschweiler and Michael Wagner
The Score-P measurement system for parallel performance

Felix Wolf
German Research School for Simulation Sciences
Higher degrees of parallelism

• Optimization of applications more difficult
  – Increasing machine & application complexity

• High demands on scalability of performance tools
Fragmentation of tools landscape

• Several performance tools co-exist
  – With different features
  – But also with overlapping functionality
  – Each comes with its own proprietary measurement system and output formats
    • Limited or expensive interoperability
    • Major effort is spent on their evolution and maintenance
    • Simultaneous installation cumbersome

Vampir

Scalasca

TAU

Periscope

VampirTrace

OTF

EPILOG / CUBE

TAU native formats

Online measurement
Objectives

• Make common part a community effort
• Improve interoperability
• Save manpower by sharing resources
• Invest this manpower in analysis functionality
• Simplify joint installation of tools
• Avoid the pitfalls of earlier community efforts
  - Start with small group of partners
  - Build on extensive history of collaboration
A unified performance measurement infrastructure

- **Vampir**
  - Visualization of event traces

- **Scalasca**
  - Large-scale analyses
  - Automatic detection of wait states

- **TAU**
  - Universal performance tool
  - Performance database

- **Periscope**
  - Online identification of performance properties

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**Score-P measurement system**

- Event traces (OTF 2)
- Call-path profiles (CUBE-4)
- Runtime interface

**Hardware counter access (PAPI)**

Application (MPI, OpenMP oder hybrid)
Score-P partners

- Technische Universität Dresden, Germany
- RWTH Aachen, Germany
- Gesellschaft für numerische Simulation mbH Braunschweig, Germany
- University of Oregon, Eugene, USA
- Forschungszentrum Jülich, Germany
- German Research School for Simulation Sciences, Jülich/Aachen, Germany
- Technische Universität München, Germany
Design goals

• Functional requirements
  – Performance data types: profiles, traces
  – Initially direct instrumentation, later also sampling
  – Offline and online access
  – Metrics: time, communication metrics and hardware counters
  – Initially MPI 2 and OpenMP 3, later also accelerators (CUDA, OpenCL)

• Non-functional requirements
  – Portability: all major HPC platforms
  – Scalability: petascale
  – Low measurement overhead
  – Easy installation through UNITE framework
  – Robustness
  – Open source: New BSD license
Instrumentation

• Compiler instrumentation
• MPI library interposition
• Automatic source-code instrumentation of OpenMP constructs via Opari2
• Manual source code instrumentation
• Automatic source-code instrumentation via TAU instrumentor
CUBE-4

• Latest version of a family of profiling formats
  – Still under development

• Representation of three-dimensional performance space
  – Metric, call path, process or thread

• File organization
  – Metadata stored as XML file
  – Metric values stored in binary format
    • Two files per metric: data + index for storage-efficient sparse representation

• Optimized for
  – High write bandwidth
  – Fast interactive analysis through incremental loading
CUBE-4 cont.

- Will comes with read and write API plus GUI for interactive exploration
- Version 3 available at www.scalasca.org/cube
- CUBE-3 used by
  - Scalasca
  - Marmot
  - ompP
  - TAU
Projects & sponsors

• SILC (2009 – 2011)
  – Initial version
• PRIMA (2009 – 2012)
  – Integration with TAU
• H4H (2010 – 2013)
  – Heterogeneous architectures
Status and schedule

• Initial prototype exists with support for the full tool chain
  – Technology preview available
• First release planned for end of 2011
• Further information
  – www.score-p.org
  – Flyer available in this room
Scalasca

Felix Wolf
German Research School for Simulation Sciences
• Performance-analysis toolset for large-scale parallel codes
  – MPI and OpenMP
• Performance overview via call-path profiling
• Identification of wait states via event tracing
• Open source: New BSD
• www.scalasca.org/
Scalasca directions

• Profiling
  – Analysis of time-dependent behavior

• Tracing
  – Identification of wait states and their root causes

• Higher degrees of scalability

• More info
  – www.scalasca.org
  – JSC booth #1451
Score-P Online Analysis Interface

Michael Gerndt, TU München
Score-P Online Access Interface

• **Online Access (OA) Interface** enables performance analysis tools to employ the Score-P monitoring infrastructure at runtime remotely over TCP/IP.

• **Highlights of online performance analysis:**
  – Finer grained measurements configuration
  – Multiple performance experiments within one run
  – Remote analysis with measurements acquisition over sockets
  – Faster analysis: one iteration of the time loop could be enough
  – No need to dump measurements into file

• **Features** of the Score-P OA
  – Configure Scope-P
  – Retrieve measured performance data while application is still running
  – Control application execution, allowing multiple measurement iterations

• Score-P OA enables online tools such as **Periscope**
Online Analysis with Score-P

Monitoring Request Interface (MRI)

- `<request_list>` = `<request>`; `<request>`
- `<request>` = `<configuration_request>`
  - `<data_request>`
- `<config_request>` = `CONFIG GLOBAL <request>`
- `<request>` = `MPI` | `<counter_name>` | `TIME` | `ALL`
- `<data_request>` = `GET <data_type>`
- `<data_type>` = `CONTEXTS` | `MEASUREMENTS` | `REGION_DECLS` | `METRIC_DECLS` | `STATIC_PROFILE`
- `<exec_request>` = `TERMINATE` | `RUNTOSTART` | `RUNTOEND`

Analysis Tool

- `CONFIG GLOBAL MPI; CONFIG GLOBAL TIME; RUNTOEND`
- `GET CONTEXTS;`
- `GET MEASUREMENTS;`
- `GET REGION_DECLS;`
- `GET METRIC_DECLS;`
- `GET STATIC_PROFILE;`
- `RUNTOSTART`

Score-P

- `Score-P call-path profiling`
- `Monitoring Request Interface (MRI)`
- `Main loop`
- `Application`
- `Init`
- `OA_Phase_Begin`
- `Finalize`
- `OA_Phase_End`
- `Static profile buffer`
- `Call-path profile buffers`
- `MONITORING_REQUEST_INTERFACE_REQUEST_LIST` = `<request>`
- `MONITORING_REQUEST_INTERFACE_REQUEST` = `<configuration_request>`
- `MONITORING_REQUEST_INTERFACE_CONFIG_REQUEST` = `CONFIG GLOBAL <request>`
- `MONITORING_REQUEST_INTERFACE_REQUEST` = `MPI` | `<counter_name>` | `TIME` | `ALL`
- `MONITORING_REQUEST_INTERFACE_DATA_REQUEST` = `GET <data_type>`
- `MONITORING_REQUEST_INTERFACE_DATA_TYPE` = `CONTEXTS` | `MEASUREMENTS` | `REGION_DECLS` | `METRIC_DECLS` | `STATIC_PROFILE`
- `MONITORING_REQUEST_INTERFACE_EXEC_REQUEST` = `TERMINATE` | `RUNTOSTART` | `RUNTOEND`

Application

- `file`: `work.c`
- `line`: `156`
- `metric`: `time`
- `value`: `14521.2`
- `rank`: `7`
MPI Wait Time profiling

- Automatic detection of MPI wait time patterns
- On-the-fly measurement
- No tracing required
- Nx1, 1xN, NxN, blocking, non-blocking
Periscope on top of Score-P

Graphical User Interface

Interactive frontend

Eclipse-based GUI

Analysis control

Agent network

Score-P Online Access Interface
TAU Performance System®

Sameer Shende, University of Oregon
• Comprehensive Profiling and Tracing
  – Widely ported to all HPC systems
  – CUDA, OpenCL
  – C, C++, Fortran, Chapel, UPC, Python, Java (JVMTI)
  – MPI, OpenMP, Pthread, SHMEM, combination...

• Instrumentation, Measurement, and Analysis
  – Interfaces with Score-P, Scalasca, VampirTrace, PAPI
  – Supports binary rewriting (tau_run), automatic source instrumentation (tau_f90.sh), runtime preloading (tau_exec)
Motivation

• Quest for improved runtime efficiency
  – TAU uses tables based lookup of callpath entities
  – Score-P provides a more efficient tree based data structure
  – Reduces runtime dilation
  – Allows TAU to generate traces that do not require merging or conversion
  – Scalable tracing solutions with Vampir
Usage

```bash
> setenv TAU_MAKEFILE $TAU/Makefile.tau-mpi-pdt-scorep
> make F90=tau_f90.sh CC=tau_cc.sh CXX=tau_cxx.sh
> setenv SCOREP_ENABLE_PROFILING 1
> setenv SCOREP_ProfileFormat TauSnapshot
> mpirun -np 4 ./matmult
Process 2 of 4 is active
Process 1 of 4 is active Process 3 of 4 is active

Process 0 of 4 is active
c( 1000 , 1000 ) = 5005000000.000000

> ls -l scorep-20101112_2035_34194/
total 20
drwxr-xr-x 2 sameer paraducks 4096 Nov 12 20:35 tau
drwxr-xr-x 2 sameer paraducks 4096 Nov 12 20:35 traces
-rw-r--r-- 1 sameer paraducks 7225 Nov 12 20:35 traces.def
-rw-r--r-- 1 sameer paraducks 182 Nov 12 20:35 traces.otf2
> cd scorep-20101112_2035_34194/tau/
> paraprof -f snapshot &
```
Generating TAU data with Score-P

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### TAU: ParaProf: Mean Data - /mnt/netapp/home1/sameer/workshop/matmul/SCOREP-20161120_0535.3

#### Metric: TIME

<table>
<thead>
<tr>
<th>Name</th>
<th>Exclusive</th>
<th>Inclusive</th>
<th>Calls</th>
<th>Child Calls</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAIN</td>
<td>0.008</td>
<td>7.913</td>
<td>1</td>
<td>1,998</td>
</tr>
<tr>
<td>MPI_Bcast</td>
<td>0.153</td>
<td>0.153</td>
<td>1,000</td>
<td>0</td>
</tr>
<tr>
<td>MPI_Comp.rank</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>MPI_Comp.size</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>MPI_Finalize</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>MPI_Init</td>
<td>1.087</td>
<td>1.087</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>MPI_Recv</td>
<td>0.15</td>
<td>0.15</td>
<td>332</td>
<td>0</td>
</tr>
<tr>
<td>MPI_Send</td>
<td>3.27</td>
<td>3.27</td>
<td>331</td>
<td>0</td>
</tr>
<tr>
<td>MULTIPLY_MATRICES</td>
<td>3.245</td>
<td>3.245</td>
<td>331</td>
<td>0</td>
</tr>
</tbody>
</table>

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### TAU: ParaProf: Thread Statistics: n,0,0,0 - /mnt/netapp/home1/sameer/workshop/matmul/SCOREP-20161120_0535.3
TAU’s Paraprof 3D Profile Browser
Status and release schedule

• TAU v2.20 released at SC’10 has full support for Score-P measurement
• ./configure --scorep=<dir> ; make install
  And use $TAU/Makefile.tau-*scorep*
TAU Acknowledgements

- Department of Energy (DOE)
  - Office of Science
    - MICS, Argonne National Lab
  - ASC/NNSA
    - University of Utah ASC/NNSA Level 1
    - ASC/NNSA, Lawrence Livermore National Lab
- Department of Defense (DoD)
  - HPC Modernization Office (HPCMO)
- NSF SDCI and SI2 programs
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- TU Dresden
- ParaTools, Inc.
Conclusions and Discussion

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Score-P Technology Demonstration

• First announcement of next generation tools infrastructure

• More information and future updates at

http://www.score-p.org

• Technology preview tarball available
  – Early functional version, try with SMG2K benchmark
  – For interested HPC tool developers
  – Not yet recommended for users or productive use
Thank you for your attention!

Questions?
Comments?